

A decade of GRB follow-up by BOOTES in Spain (2003-2013)

Martin Jelínek^{1,2*}, Alberto J. Castro-Tirado^{2,3}, Ronan Cunniffe², Javier Gorosabel^{2,4,5,†}, Stanislav Vítek⁶, Petr Kubánek^{7,8}, Antonio de Ugarte Postigo², Sergey Guziy², Juan C. Tello², Petr Páta⁶, Rubén Sánchez-Ramírez², Samantha Oates², Soomin Jeong^{9,2}, Jan Štrobl¹, Sebastián Castillo-Carrión¹⁰, Tomás Mateo Sanguino¹¹, Ovidio Rabaza¹², Dolores Pérez-Ramírez^{13,†}, Rafael Fernández-Muñoz¹⁴, Benito A. de la Morena Carretero¹⁵, René Hudec^{1,6}, Víctor Reglero⁸, and Lola Sabau-Graziati¹⁶

¹ Astronomický Ústav AV ČR, Ondřejov, (ASÚ AV ČR), Ondřejov, ČR

² Instituto de Astrofísica de Andalucía, IAA-CSIC, 18008 Granada, Spain

³ Departamento de Ingeniería de Sistemas y Automática (Unidad Asociada al CSIC), Universidad de Málaga, 29010 Málaga, Spain

⁴ Unidad Asociada Grupo Ciencia Planetarias UPV/EHU-IAA/CSIC, Departamento de Física Aplicada I, E.T.S. Ingeniería, Universidad del País Vasco UPV/EHU, Alameda de Urquijo s/n, E-48013 Bilbao, Spain.

⁵ Ikerbasque, Basque Foundation for Science, Alameda de Urquijo 36-5, E-48008 Bilbao, Spain

⁶ České Vysoké Učení Technické, Fakulta Elektrotechnická, (FEL ČVUT), Praha, ČR

⁷ Fyzikální ústav AV ČR, Na Slovance 2, CZ-182 21 Praha 8, Czech Republic

⁸ Image Processing Laboratory, Univ. de Valencia, Burjassot (Valencia), Spain

⁹ Institute for Science and Technology in Space, Natural Science Campus, SungKyunKwan University, 440-746, Suwon, Korea

¹⁰ Universidad de Málaga, Campus de Teatinos, Málaga, Spain

¹¹ Departamento de Ingeniería de Sistemas y Automática, Universidad de Huelva, E.P.S. de La Rábida (Huelva), Spain

¹² Department of Civil Engineering, University of Granada, CP 18071, Spain.

¹³ Universidad de Jaén, Campus las Lagunillas, 23071 Jaén, Spain

¹⁴ Instituto de Hortofruticultura Subtropical y Mediterránea "La Mayora" (IHSM-CSIC), Algarrobo (Málaga), 29750 Spain

¹⁵ Estación de Sondeos Atmosféricos (ESAt) de El Arenosillo (CEDEA-INTA), Mazagón, Huelva, Spain

¹⁶ División de Ciencias del Espacio (INTA), Torrejón de Ardoz (Madrid), Spain

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ABSTRACT

This article covers ten years of GRB follow-ups by the Spanish BOOTES stations: 71 follow-ups providing 23 detections. Follow-ups by BOOTES-1B from 2005 to 2008 were given in the previous article, and are here reviewed, updated, and include additional detection data points as the former article merely stated their existence. The all-sky cameras CASSANDRA have not yet detected any GRB optical afterglows, but limits are reported where available.

Dedicated to the memory of Dolores Pérez-Ramírez and Javier Gorosabel, who passed away while this paper was in preparation

Key words. Gamma-rays: catalogs, gamma-ray burst: general + individual, telescopes

1. Introduction

Ever since the discovery of Gamma-ray bursts (GRB) in 1967 (Klebesadel et al., 1973), it was hoped to discover their counterparts at other wavelengths. The early GRB-related transient searching methods varied (wide-field optical systems as well as deep searches were being employed), but, given the coarse gamma-ray-based GRB localizations provided, generally lacked either sensitivity or good reaction time. The eventual discovery of GRB optical counterparts was done only when an X-ray follow-up telescope was available on the Beppo-SAX satellite (Costa et al., 1997). The optical afterglow could then be searched for with a large telescope in a small errorbox provided by the dis-

covery of the X-ray afterglow. The first optical afterglow of a Gamma-ray burst was discovered this way in 1997 (van Paradijs et al., 1997).

Since then, astronomers have been trying to minimize the time delay between receiving the position and the start of observations – by both personal dedication and by automating the telescope reaction. The ultimate step in automation, to minimize the time delay, is a full robotization of the observatory to eliminate any human intervention in the follow-up process. This way, the reaction time can be minimized from ~10 minute limit that can be achieved with a human operated telescope to below 10 seconds. With improvements in computational methods and in image processing speed, blind (non follow-up) wide-field methods are starting to be practical in the search for optical transients. Although limited in magnitude range, they have al-

Send offprint requests to: Martin Jelínek

* email: mates@iaa.es

ready provided important observations of the optical emission simultaneous to the gamma-ray production of a GRB (Racusin et al., 2008).

Since 1997, the robotic telescope network BOOTES has been part of the effort to follow-up gamma-ray burst events (Castro-Tirado et al., 2004). As of now, the network of robotic telescopes BOOTES consists of six telescopes around the globe, dedicated primarily to GRB afterglow follow-up. We present the results of our GRB follow-up programme by two telescopes of the network – BOOTES-1B and BOOTES-2 and by the respective stationary very wide field cameras (CASSANDRA). This text covers eleven years of GRB follow-ups: 71 follow-ups providing 21 detections.

Different instruments have been part of BOOTES during the years in question: a 30 cm telescope which was used for most of the time at BOOTES-1 station but at periods also at BOOTES-2, the fast-moving 60 cm telescope at BOOTES-2 (Telma), and also two all-sky cameras, CASSANDRA1 at BOOTES-1 and CASSANDRA2 at BOOTES-2. Results from CASSANDRAs are included where available, without paying attention to the complete sample.

This article is a follow-up of a previous article: Jelínek et al. (2010) which provided detailed description of evolution of BOOTES-1B, and analysis of efficiency of a system dedicated to GRB follow-up based on real data obtained during four years between 2005 and 2008. This work is a catalogue of BOOTES-1B and BOOTES-2 GRB observations between 2003 and 2013; it is complete in providing information about successfully followed-up events, but does not provide analysis of missed triggers as did the previous article.

1.1. BOOTES-1B

BOOTES-1 observatory is located at the atmospheric sounding station at El Arenosillo, Huelva, Spain (at lat: $37^{\circ}06'14''\text{N}$, long: $06^{\circ}44'02''\text{W}$). Over time, distinct system configurations were used, including also two 8 inch S-C telescopes, as described in Jelínek et al. (2010), the primary instrument of BOOTES-1B is a D=30 cm Schmidt-Cassegrain optical tube assembly with a CCD camera. Prior to June 15, 2007, Bessel *VRI* filters were being used as noted with the observations, any observations obtained after this date have been obtained without filter (*C* or clear). We calibrate these observations against *R*-band, which, in the case of no color evolution of the optical counterpart, is expected to result in a small (~ 0.1 mag) constant offset in magnitude.

1.2. BOOTES-2

BOOTES-2 is located at CSIC's experimental station La Mayora (Instituto de Hortofruticultura Subtropical IHSM-CSIC) (at lat: $36^{\circ}45'33''\text{N}$, long: $04^{\circ}02'27''\text{W}$), 240 km from BOOTES-1. It was originally equipped with an identical 30 cm Schmidt-Cassegrain telescope to that at BOOTES-1B. In 2007 the telescope was upgraded to a lightweight 60 cm Ritchey-Chrétien telescope on a fast-slewing NTM-500 mount, both provided by Astelco. The camera was upgraded at the same time to an Andor iXon 1024 \times 1024 EMCCD, and in 2012 the capabilities were extended yet again to low resolution spectroscopy, by the

installation of the imaging spectrograph COLORES of our own design and construction (Rabaza et al., 2013). Bessel magnitudes are calibrated to Vega system, SDSS to AB.

2. Optical follow-up of GRB events

Here we will detail the individual results for each of the 23 events followed-up and detected in 2003 – 2013. Each GRB is given a short introductory paragraph as a reminder of the basic observational properties of the event. Although we do not discuss the properties at other wavelengths, we try to include a comprehensive reference of literature relevant to each burst. As GCN reports usually summarise the relevant GCN circular traffic, we have omitted the raw GCN circulars except for events for which a GCN report or other more exhaustive paper is unavailable.

Further 48 follow-ups which resulted in detection limits are included in tables 1 and 2, but are not given any further attention.

One by one, we show all the successful follow-ups that these telescopes have performed during the first ten years of the *Swift* era, and since the transition of the BOOTES network to the RTS-2 (Kubánek et al., 2004) observatory control system, which was for the first time installed at BOOTES-2 in 2003, and during the summer of 2004 at BOOTES-1.

GRB 050525A A bright low-redshift ($z = 0.606$) localized by *Swift* (Blustin et al., 2006). Plenty of optical data, including the signature of the associated supernova sn2005nc (Della Valle et al., 2006; Resmi et al., 2012).

GRB 050525A was the first BOOTES-1B burst for which a detection was obtained. The telescope started the first exposure 28 s after receiving the notice, 383 s after the GRB trigger. An optical afterglow with $V \simeq 16$ was detected. A weak detection of a bright GRB implied a reexamination of observing strategies employed by BOOTES. The largest, 30 cm telescope was changed to make *R*-band imaging instead of using the field spectrograph to greatly improve sensitivity in terms of limiting magnitude. The

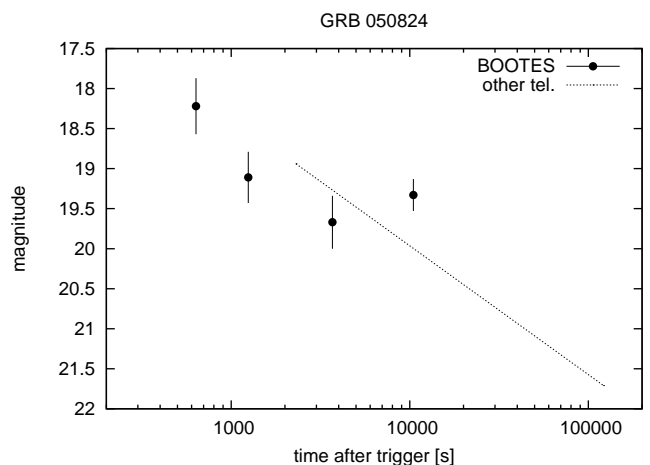


Fig. 1 The optical light curve of GRB 050824, the optical lightcurve represents behaviour seen by Sollerman et al. (2007).

20 cm telescopes were still observing with V+I filters (for details see Jelínek et al., 2010).

This burst was covered in real time by both All Sky Cameras of BOOTES (CASSANDRA1 and 2), providing an unfiltered limit of > 9.0 (de Ugarte Postigo et al., 2005). BOOTES observation of this GRB is included in Resmi et al. (2012).

GRB050824 A dim burst detected by *Swift*. The optical afterglow of this GRB discovered with the 1.5 m telescope at OSN, redshift $z = 0.83$ determined by VLT (Sollerman et al., 2007).

BOOTES-1B was the first telescope to observe this optical transient, starting 636 s after the trigger with $R \simeq 17.5$. The weather was not stable and the focus not perfect, but BOOTES-1B worked as expected. In the end, several hours of data were obtained. BOOTES observation of this GRB is included in Sollerman et al. (2007).

GRB050922C A *Swift* short and intense long burst (Norris et al., 2005; Krimm et al., 2005) that was observed also by *HETE2* (Crew et al., 2005). Optical afterglow mag ~ 15 , $z = 2.198$ (Jakobsson et al., 2005).

Due to clouds, the limiting magnitude of BOOTES-1B dropped from ~ 17.0 for a 30 s exposure to mere 12.9. The afterglow was eventually detected with the *R*-band camera (at the 30 cm telescope) during gaps between passing clouds. The first weak detection was obtained 228 s after the GRB trigger and gave $R \simeq 14.6$.

GRB051109A A burst detected by *Swift* (Fenimore et al., 2005). Optical afterglow mag 15, redshift $z = 2.346$ (Quimby et al., 2005), optical lightcurve by Mirabal et al. (2006).

At BOOTES-1B the image acquisition started 54.8 s after the burst with the 30 cm telescope in *R*-band and one of the 20 cm telescopes in *I*-band (Jelínek et al., 2005). There were still a number of performance problems – most importantly synchronization between cameras such that when the

telescope position was to be changed, both cameras had to be idle. As the 30 cm telescope was taking shorter exposures, extra exposures could have been made while waiting for the longer exposures being taken at the 20 cm to finish. The 20 cm detection is, after critical revision, only at the level of $2\text{-}\sigma$. The *R*-band observation shows the object until about 20 minutes after the GRB, when it becomes too dim to measure in the vicinity of a 17.5 m nearby star. Mean decay rate observed by BOOTES is $\alpha = 0.63 \pm 0.06$ ($F_{\text{opt}} \sim t^{-\alpha}$).

The relatively shallow decay observed by BOOTES is in close agreement with what was observed several minutes later by the 2.4 m MDM ($\alpha = 0.62 \pm 0.03$) and according to an unofficial report (Mirabal et al., 2005) there was a decay change later, by about 3 h after the burst to $\alpha = 0.89 \pm 0.05$.

GRB080330 A rather bright long burst detected by *Swift*. Afterglow reported to be detected by UVOT, TAROT, ROTSE-III, Liverpool Telescope and GROND. Spectroscopic redshift $z = 1.51$ by NOT (Mao et al., 2008).

This GRB happened during the first day recommissioning of BOOTES-1B after its move from the BOOTES-2 site at La Mayora. The GCN client was not yet operational and at the time of the GRB we were focusing the telescope. The first image was obtained 379 s after the GRB trigger and the optical afterglow was detected with magnitude ~ 16.3 on the first image. A bug in the centering algorithm caused a loss of part subsequent data. Further detections were obtained starting 21 min after the GRB when the problem was fixed.

The lightcurve (as seen by Yuan et al. 2008) seems to show an optical flare and then a possible hydrodynamic peak. The data of BOOTES, however, trace only the final part of this behaviour, where the decay accelerates after passing through the hydrodynamic peak.

GRB080413A A rather bright GRB detected by *Swift*, detected also by *Suzaku*-WAM, optical afterglow by ROTSE-

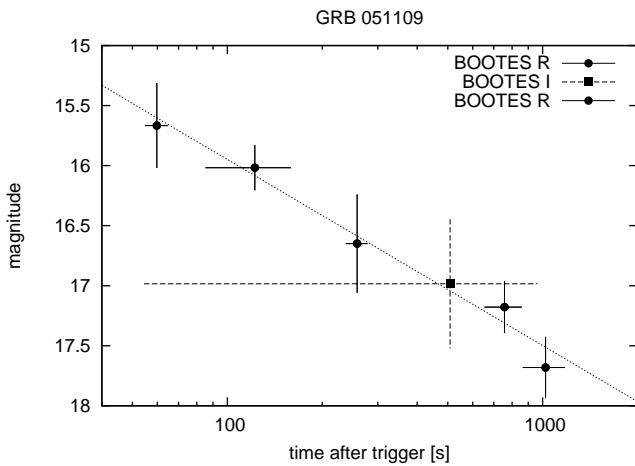


Fig. 2 The optical light curve of GRB 051109A. The dotted line represents the optical decay observed by Mirabal et al. (2006).

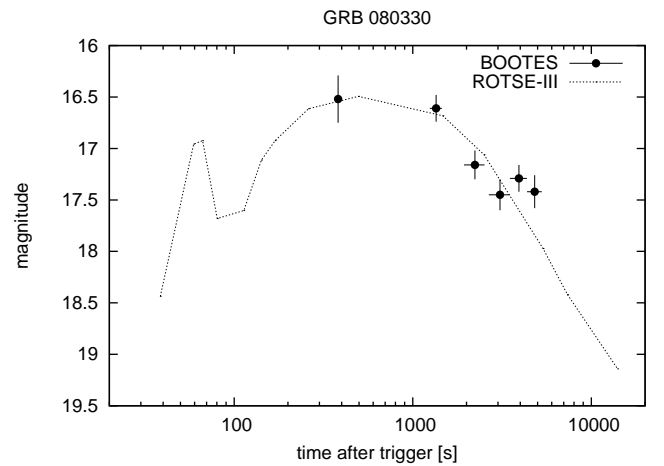


Fig. 3 The optical light curve of GRB 080330. The dotted line shows how the lightcurve as seen by ROTSE-III (Yuan et al., 2008)

III (Yuan et al., 2008), redshift $z = 2.433$ by VLT+UVES (Marshall et al., 2008).

BOOTES-1B started obtaining images of the GRB 080413A just 60.7s after the trigger (46.3s after reception of the alert). An $R \simeq 13.3$ magnitude decaying optical afterglow was found, see. Fig. 4 (Kubánek et al., 2008, *Jelínek et al., in prep.*)

GRB 080430 A burst detected by *Swift*. It was a widely observed, low-redshift $z \simeq 0.75$ optical afterglow with a slowly decaying optical afterglow (Guidorzi et al., 2008). Observed also at very high energies by *MAGIC* without detection (Aleksić et al., 2010).

BOOTES-1B obtained the first image of this GRB 34.4s after the trigger. An optical transient was detected on combined unfiltered images with a magnitude $\simeq 15.5$ (Jelínek et al., 2008).

GRB 080603B A long GRB localized by *Swift*, detected also by *Konus-Wind* and by *INTEGRAL* (Rau et al., 2005). Bright optical afterglow, extensive follow-up, redshift $z = 2.69$ (Mangano et al., 2008).

This GRB happened in Spain during sunset. We obtained first useful images starting one hour after the trigger. An $R \simeq 17.4$ optical transient was detected with both BOOTES-1B and BOOTES-2 see Fig. 5. BOOTES observation of this GRB is included in Jelínek et al. (2012b).

GRB 080605 A long burst detected by *Swift* (Sbarufatti et al., 2008). The host was found to be a metal enriched star forming galaxy at redshift $z = 1.64$ (Krühler et al., 2012), and exhibited the 2175 Å extinction feature (Zafar et al., 2012).

GRB 080605 was observed by both BOOTES-1B (28 photometric points) and BOOTES-2 (5 photometric points) starting 44s after the trigger. A rapidly decaying optical afterglow ($\alpha = 1.27 \pm 0.04$) with $R = 14.7$ on the first images was found see Fig. 6. All BOOTES data are included in Jelínek et al. (2013).

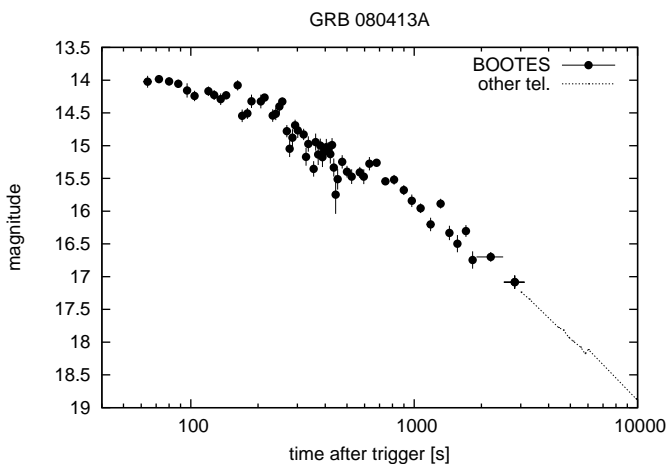


Fig. 4 The optical light curve of GRB 080413A.

GRB 090313 GRB by *Swift*, no prompt X-rays (Mao et al., 2009). An optical afterglow peaking at $R \sim 15.6$. Extensive optical + infrared follow-up, the first GRB to be observed by X-Shooter. Also detected by various observatories in radio. Redshift $z = 3.375$ (de Ugarte Postigo et al., 2010a; Melandri et al., 2010).

The GRB happened during daytime for BOOTES-1B and it was followed-up manually. Due to the proximity of the Moon and limitations of then-new CCD camera driver, many 2s exposures were taken to be combined later. The optical afterglow was detected with magnitude $\sim 18.3 \pm 0.4$ on a 635×2 s (=21 min) exposure with the mid-time 11.96 h after the GRB trigger.

GRB 090813 A long GRB by *Swift*, suspected of being higher- z , observed also by *Konus-Wind* and *Fermi-GBM* (Cummings et al., 2009). Optical counterpart by the 1.23 m

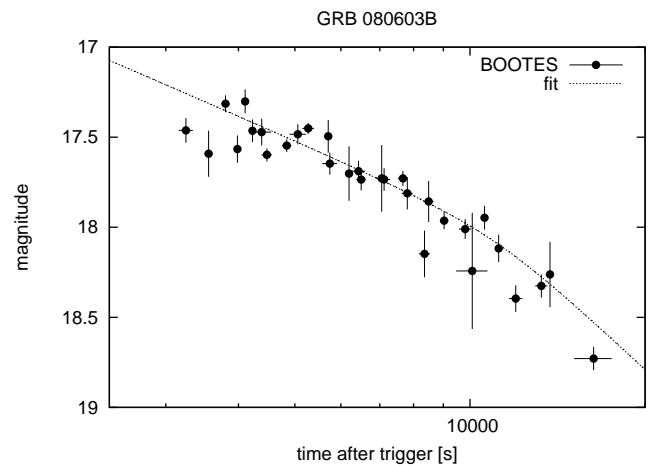


Fig. 5 The optical light curve of GRB 080603B (Jelínek et al., 2012b).

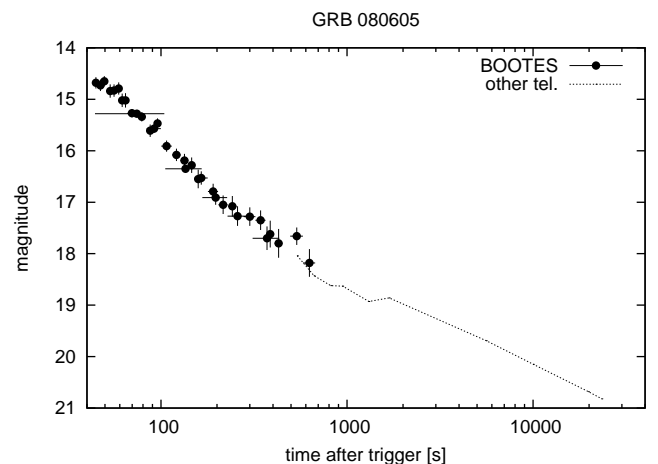


Fig. 6 The optical light curve of GRB 080605 (Jelínek et al., 2013), the dotted line is behaviour observed by Rumyantsev & Pozanenko (2008) and Zafar et al. (2012).

telescope at Calar Alto with a magnitude of $I = 17.0$ (Gorosabel et al., 2009).

BOOTES-1B started observation 53s after the GRB, taking 10s unfiltered exposures. The optical transient was weakly detected on a combined image of 10×10 s whose exposure mean time was 630s after the burst. The optical counterpart was found having $R = 17.9 \pm 0.3$. Given that the previous and subsequent images did not show any OT detection, we might speculate about the optical emission peaking at about this time. Also the brightness is much weaker than might be expected from the detection by Gorosabel et al. (2009), supporting the high redshift origin.

GRB100418A A weak long burst detected by *Swift* (Marshall et al., 2011) with a peculiar, late-peaking optical afterglow with $z = 0.6239$ (de Ugarte Postigo et al., 2011). Also detected in radio (Moin et al., 2013).

The first image of the GRB location was taken by BOOTES-2 at 21:50 UT (40min after the GRB trigger). The rising optical afterglow was detected for the first time on an image obtained as a sum of 23 images, with an exposure mid-time 107 minutes after the GRB trigger. The optical emission peaked at magnitude $R=18.7$ another hour later, at an image with the mid-time 163min after the trigger. A slow decay followed, which permitted us to detect the optical counterpart until 8 days after the GRB.

Because of a mount problem, many images were lost (pointed somewhere else) and the potential of the telescope was not fully used. Eventually, after combining images when appropriate, 11 photometric points were obtained. A rising part of the optical afterglow was seen that way.

GRB100901A A long burst from *Swift*. Bright, slowly decaying optical afterglow discovered by UVOT. Redshift $z = 1.408$. Detected also by SMA at 345 GHz (Immler et al., 2010; Gorbovskey et al., 2012; Hartoog et al., 2013).

The burst happened in daytime in Spain and the position became available only almost ten hours later after

the sunset. The afterglow was still well detected with magnitude $R \simeq 17.5$ at the beginning. BOOTES-2 had some problems with CCD cooling, and some images were useless. The afterglow was detected also the following night with $R = 19.35$.

GRB101112A An *INTEGRAL*-localized burst (Gotz et al., 2010), also detected by *Fermi*-GBM (Goldstein, 2010), *Konus*-Wind (Golenetskii et al., 2010) and *Swift*-XRT (Evans & Krimm, 2010). Optical afterglow discovered independently by BOOTES-2 and Liverpool Telescope (Guidorzi et al., 2010). Detected also in radio (Chandra et al., 2010).

BOOTES-2 reacted to the GRB101112A and started to observe 47s after the GRB. A set of 3s exposures was taken, but due to technical problems with the mount a significant amount of observing time was lost. An optical afterglow was discovered and reported (de Ugarte Postigo et al., 2010b). The optical lightcurve exhibited first a decay, then a sud-

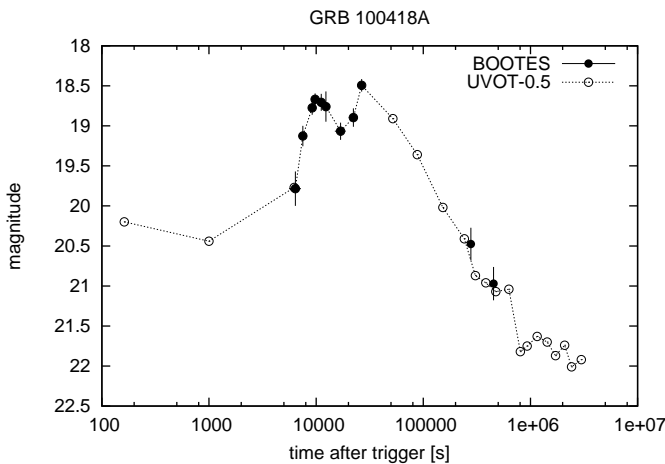


Fig. 7 The bizarre optical light curve of GRB100418A. Combination of BOOTES and UVOT data (Marshall et al., 2011). UVOT points were shifted by an arbitrary constant.

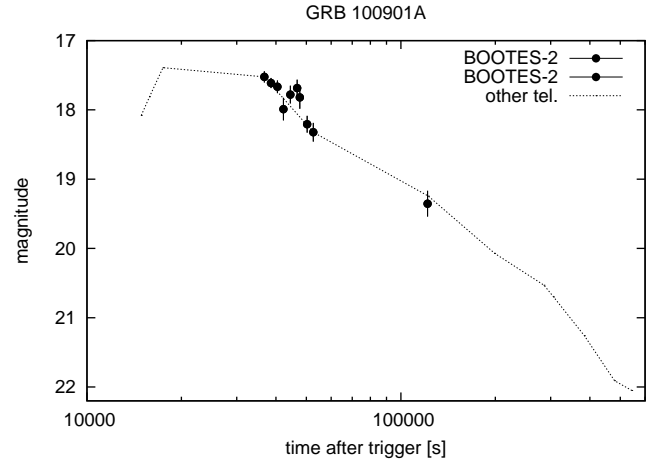


Fig. 8 The optical light curve of GRB100901A. The dotted line representing burst behaviour is based on observations by Gorbovskey et al. (2012), Kann et al. (2010) and Rumyantsev et al. (2010).

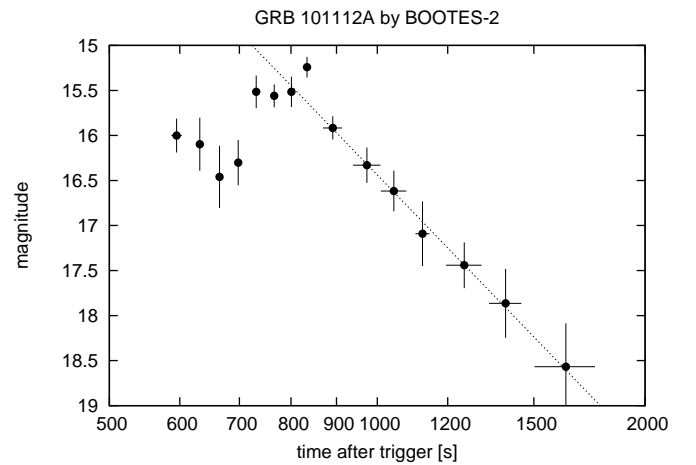


Fig. 9 The optical light curve of GRB101112A.

den rise to a peak at about 800s after the trigger, and finally a surprisingly fast decay with $\alpha \simeq -4$. This behaviour seemed more like an optical flare than a “proper” GRB afterglow, but there does not seem to be contemporaneous high-energy data to make a firm statement.

GRB 110205A A very long and bright burst by *Swift*. Detected also by *Konus-Wind* and *Suzaku-WAM*, optical afterglow peaking at $R \sim 14.0$, extensive multiwavelength follow-up, $z = 2.22$ “*Textbook burst*” (Zheng et al., 2012; Gendre et al., 2012).

BOOTES-1B reacted automatically to the *Swift* trigger. First 10s unfiltered exposure was obtained 102s after the beginning of the GRB (with $T_{90} = 257$ s) i.e. while the gamma-ray emission was still taking place. After taking 18 images, the observatory triggered on a false alarm from the rain detector, which caused the observation to be stopped for 20 minutes. After resuming the observation, 3×30 s images were obtained and another false alert struck over. This alert was remotely overridden by P. Kubánek, so that all 20 minutes were not lost. From then on, the observation continued until sunrise. The afterglow is well detected in the images until 2.2 hours after the GRB. 16 photometric points from combined images were eventually published.

BOOTES-2 started observations 15 min after the trigger, clearly detecting the afterglow in *R*-band until 3.2 hours after the burst. 13 photometric points were obtained. The delay was caused by technical problems. BOOTES observations of this GRB are included in Zheng et al. (2012).

GRB 110213A A bright burst detected by *Swift*, detected also by *Konus-Wind* and *Fermi-GBM*. Optical afterglow $R \sim 14.6$, extensive follow-up (D’Elia et al., 2011).

BOOTES-1B started to observe 15 hours after the GRB (the position was below horizon at the time of the trigger) and continued for an hour, eventually, 100×30 s unfiltered images were combined, the OT brightness calibrated against USNO-A2 is 18.3 ± 0.3 at the exposure mid-time of 15.5 h after the GRB trigger.

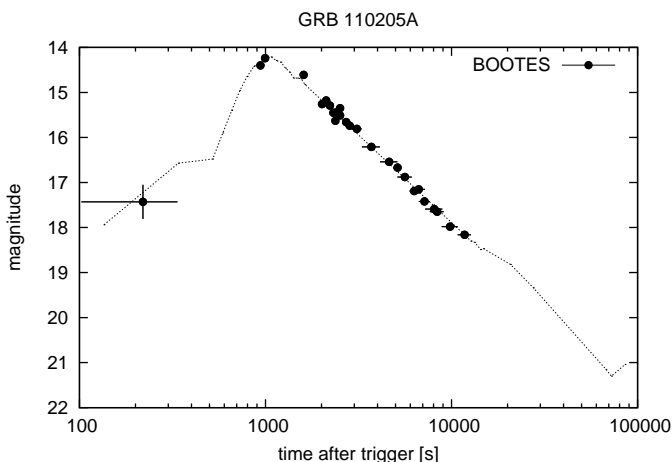


Fig. 10 The optical light curve of GRB 110205A.

GRB 120326A A *Swift*-detected burst. Afterglow discovered by Tarot (Klotz et al., 2012a). Long-lived optical emission, redshift $z = 1.78$ by GTC. Detected also by *Fermi-GBM* and *Suzaku-WAM* (Siegel et al., 2013, and references therein).

At BOOTES-1B the mount failed, because of the serial port communication failure. After a manual recovery, 40 minutes after the GRB, images were taken in hope for a detection, but the counterpart with the brightness of $R \sim 19.5$ was detected only at about 2σ level.

GRB 120327A A bright burst by *Swift* with an afterglow discovered by UVOT (Sbarufatti et al., 2012). Redshift $z = 2.813$ (D’Elia, 2013). Extensive optical follow-up.

BOOTES-1B reacted in 41 min (similar failure as the day before: the mount failed, because of the serial port communication failure), obtaining a series of 20 s exposures. These images were combined to get 600 s effective exposures and permitted detection of the afterglow on six such images. The brightness was decaying from $R=17.5$ to $R=18.6$.

All-sky camera at BOOTES-1 (CASSANDRA1) covered the event in real time and detected nothing down to $R \sim 7.5$ (Zanioni et al. in prep.).

GRB 121001A A bright and long *Swift*-detected GRB, originally designated as possibly galactic (D’Elia et al., 2012). Afterglow discovered by Andreev et al. (2012).

BOOTES-2 observed this trigger starting 32 min after the trigger. An optical afterglow is detected in *I*-band with $I \sim 19.7$ (Vega) for a sum of images between 20:49 – 21:52 UT (Tello et al., 2012).

GRB 121024A A bright *Swift*-detected GRB with a bright optical afterglow (Pagani et al., 2012; Klotz et al., 2012b). Detected also in radio (Laskar et al., 2012). Redshift $z = 2.298$ by Tanvir et al. (2012).

BOOTES-1B observed the optical afterglow of GRB 121024A. The observations started 40 minutes after the GRB trigger. The sum of 20 minutes of unfiltered images with a mean integration time 54 minutes after the GRB shows a weak detection of the optical afterglow with magnitude $R = 18.2 \pm 0.5$ (Jelínek et al., 2012a).

GRB 130418A A bright and long burst with a well detected optical afterglow somewhat peculiarly detected after a slew by *Swift* (de Pasquale et al., 2013). Observation by *Konus-Wind* showed that the burst started already 218s before *Swift* triggered (Golenetskii et al., 2013). Redshift $z = 1.218$ by de Ugarte Postigo et al. (2013).

BOOTES-2 obtained a large set of unfiltered, *r'*-band and *i'*-band images starting 1.5 h after the trigger. The optical afterglow is well detected in the images. The lightcurve is steadily decaying with the power-law index of $\alpha = -0.93 \pm 0.06$, with the exception of the beginning, where there is a possible flaring with peak about 0.25 mag brighter than the steady power-law.

GRB 130505A A bright and intense GRB with a 14 mag optical afterglow detected by *Swift* (Cannizzo et al., 2013). Redshift $z = 2.27$ reported by Tanvir et al. (2013).

BOOTES-2 obtained the first image of this GRB 11.94 h after the trigger. A set of 60 s exposures was obtained. Combining the first hour of images taken, we clearly detect the optical afterglow, and using the calibration provided by Kann et al. (2013), we measure $R_C = 19.26 \pm 0.06$.

GRB 130606A A high-redshift GRB detected by *Swift* (Ukwatta et al., 2013), optical afterglow discovered by BOOTES-2, redshift $z = 5.9$ by GTC (Castro-Tirado et al., 2013).

BOOTES-2 reaction to this GRB alert was actually a failure, the system did not respond as well as it should and it had to be manually overridden to perform the observations. The first image has therefore been taken as late as 13 minutes after the trigger. These observations led to a discovery of a bright afterglow not seen by *Swift*-UVOT, and prompted spectroscopic observations by 10.4m GTC, which show redshift of this event to be $z = 5.9135$. Overall, 14 photometric points in i' -band and 7 in z' -band were obtained (Castro-Tirado et al., 2013).

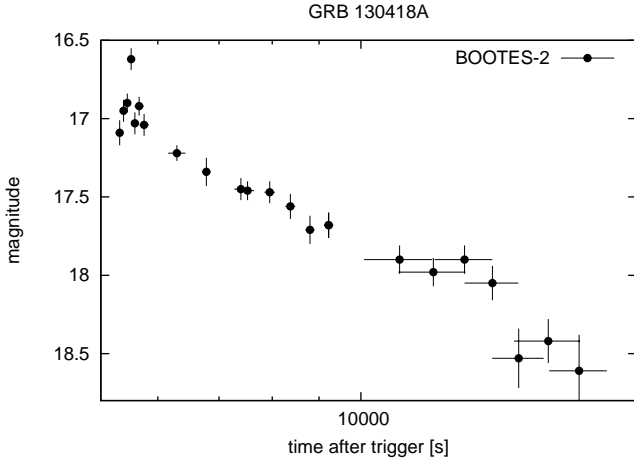


Fig. 11 The optical light curve of GRB 130418A.

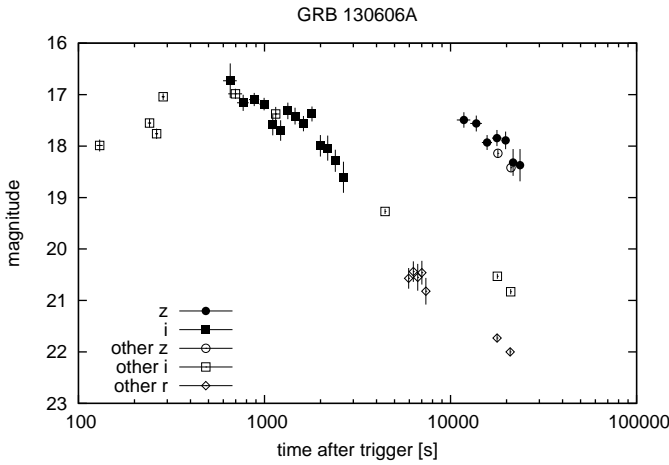


Fig. 12 The optical light curve of GRB 130606A. i' -band points were shifted 2.4 mag up to match with the z' -band points.

Table 1: BOOTES-1B GRBs in a table

GRB	ΔT	no. pts	result	ref.
030913	2 h		$V > 17.5, C > 12$	
050215B	22 m		$V > 16.5, I > 15.0$	
050505	47 m		$V > 19$	
050509A	64 m		$V > 14.9$	
050509B	62 s		$V > 11.5$	
050525A	12 m [†]	1	16.5 ± 0.4	[1]
050528	71 s		$V > 13.8, I > 13.0$	
050824	10 m	4	$R = 18.2 \pm 0.3$	[2]
050904	2 m		$R > 18.2$	[3]
050922C	4 m	3	$R = 14.6 \pm 0.4$	
051109A	55 s	6	$R = 15.7 \pm 0.4$	
051211B	42 s		$R >$	
051221B	4 m		$R >$	
060421	61 s		$R > 14$	
061110B	11 m		$R > 18$	
071101	55 s		$C > 17.0$	
071109	59 s		$C > 13.0$	
080330	6 m	6	$C = 16.5 \pm 0.2$	
080413A	61 s	61	$C \simeq 13.3$	
080430	34 s	*	$C \simeq 15.5$	
080603B	1 h	11	$C \simeq 17.4$	[4]
080605	44 s	28	$C \simeq 14.7$	[5]
081003B	41 s		$C > 17.6$	
090313	12 h	1	$C \simeq 18.3$	
090519	99 s		$C > 17.6$	
090813	53 s	1	$C \simeq 17.9$	
090814A	3 m [†]		$C > 15.8$	
090814B	53 s [†]		$C > 17.5$	
090817	24 m		$C > 16.7$	
100906A	106 s		$C > 16.5$	
110205A	102 s	16	$C \sim 14$	[6]
110212A	50 s		$C > 13.0$	
110213A	15 h	1	$C = 18.3 \pm 0.2$	
110411A	24 s		$C > 17.8$	
111016A	1.25 h		$C > 17.8$	
120326A	40 m	1	$C \sim 19.5$	
120327A	41 m [†]	6	$C = 17.5$	
120328A	7.5 m		$C > 16$	
120521C	11.7 m		$C > 20.5$	
120711B	107 s		$C > 18.2$	
120729A	10 h		$C > 19.0$	
121017A	79 s		$C > 19.0$	
121024A	40 m	1	$C = 18.2 \pm 0.5$	
121209A	42 s [†]		$C > 16.5$	
130122A	28 m		$C > 18.4$	

Note — 1. Resmi et al. (2012), 2. Sollerman et al. (2007), 3. Haislip et al. (2006), 4. Jelínek et al. (2012b), 5. Jelínek et al. (2013), 6. Zheng et al. (2012), [†] marks alerts covered in real time by wide-field camera CASSANDRA-1.

3. Summary

Eleven years of BOOTES-1B and BOOTES-2 GRB follow-up history are summarised in the textual and tabular form. Each GRB is given a short introductory paragraph as a reminder of the basic optical properties of the event. Although we do not discuss the properties in other wavelengths, we try to include a comprehensive reference of literature relevant to each burst. One by one, we show all the successful follow-ups that these telescopes have per-

Table 2: BOOTES-2 GRBs in a table

GRB	ΔT	no. pts	result	ref.
080603B		20	$R \simeq 17.4$	[1]
080605		5	$R \simeq 14.7$	[2]
090817	145 s		$R > 18.3$	
090904A	86 s		$R > 16.1$	
091202	5.5 h		> 18.3	
100219A	6.3 h		$C > 18.3$	
100418A	1.8 h	11	$C = 19.3$	
100522A	625 s		$C > 15.5$	
100526A	4 h		$r' > 14$	
100614A	6.9 m		$C > 18$	
100901A	10 h	10	$C = 17.52 \pm 0.08$	
100915A	106 s		$C > 16.5$	
101020A	5.1 h		$r' > 18.0$	
101112A	595 s	15	$C = 15.5$	
110106B	10.3 m		$C > 16.5$	
110205A	15 m	13	$R \sim 14$	[3]
110212A	32 m		$R > 16.5$	
110223A	228 s		$R > 17.6$	
120729A	13.25 h		$R > 19.4$	
120805A	25 m		$R > 18.5$	
120816A	66 m		$R > 18$	
121001A	32 m		$I > 19.7$	
121017A	3 m		$C > 18.5, i' > 19.5$	
130418A	1.5 h	21	$C = 16.8 \pm 0.06$	
130505A	11.94 h	1	$R_C = 19.26 \pm 0.06$	
130606A	13 m	21	$i' = 16.7 \pm 0.3$	
130608A	2.3 h		$C > 18.8$	
130612A	4.8 m		$C > 18.6$	
130806A	40 s		$C > 18.3$	
131202A	4.25 h		$i' > 19.7$	

Note — 1. Jelínek et al. (2012b), 2. Jelínek et al. (2013), 3. Zheng et al. (2012)

formed during the first ten years of the *Swift* era, and the transition of the BOOTES network to the RTS-2 (Kubánek et al., 2004) observatory control system, first installed at BOOTES-2 in 2003, and made definitive during the summer of 2004.

The BOOTES telescopes, in spite of their moderate apertures ($\lesssim 60$ cm) have proven to detect a significant number of afterglows – together over 20, contributing to the understanding of the early GRB phase.

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References

- Aleksić, J., Anderhub, H., Antonelli, L. A., et al. 2010, *A&A*, 517, A5
 Andreev, M., Sergeev, A., & Pozanenko, A. 2012, *GCN Circular*, 13833
 Blustin, A. J., Band, D., Barthelmy, S., et al. 2006, *ApJ*, 637, 901
 Cannizzo, J. K., Barthelmy, S. D., Cummings, J. R., Melandri, A., & de Pasquale, M. 2013, *GCN Report*, 429
 Castro-Tirado, A. J., Jelínek, M., Mateo Sanguino, T. J., de Ugarte Postigo, A., & the BOOTES team. 2004, *Astronomische Nachrichten*, 325, 679
 Castro-Tirado, A. J., Sánchez-Ramírez, R., Ellison, S. L., et al. 2013, *ArXiv e-prints*
 Chandra, P., Frail, D. A., & Cenko, S. B. 2010, *GCN Circular*, 11404
 Costa, E., Frontera, F., Heise, J., et al. 1997, *Nature*, 387, 783
 Crew, G., Ricker, G., Atteia, J.-L., et al. 2005, *GCN Circular*, 4021
 Cummings, J. R., Beardmore, A. P., & Schady, P. 2009, *GCN Report*, 240
 de Pasquale, M., Baumgartner, W. H., Beardmore, A. P., et al. 2013, *GCN Circular*, 14377
 de Ugarte Postigo, A., Goldoni, P., Thöne, C. C., et al. 2010a, *A&A*, 513, A42
 de Ugarte Postigo, A., Jelínek, M., Gorosabel, J., et al. 2005, *GCN Circular*, 3480
 de Ugarte Postigo, A., Kubánek, P., Tello, J. C., et al. 2010b, *GCN Circular*, 11398
 de Ugarte Postigo, A., Thoene, C. C., Gorosabel, J., et al. 2013, *GCN Circular*, 14380
 de Ugarte Postigo, A., Thöne, C. C., Goldoni, P., Fynbo, J. P. U., & X-shooter GRB Collaboration. 2011, *Astronomische Nachrichten*, 332, 297
 D’Elia, V. 2013, in *EAS Publications Series*, Vol. 61, *EAS Publications Series*, ed. A. J. Castro-Tirado, J. Gorosabel, & I. H. Park, 247–249
 D’Elia, V., Cummings, J. R., Stamatikos, M., et al. 2012, *GCN Report*, 392
 D’Elia, V., Stratta, G., Kuin, N. P. M., et al. 2011, *GCN Report*, 323
 Della Valle, M., Malesani, D., Bloom, J. S., et al. 2006, *ApJ*, 642, L103
 Evans, P. A. & Krimm, H. A. 2010, *GCN Circular*, 11399
 Fenimore, E., Angelini, L., Barbier, L., et al. 2005, *GCN Circular*, 4217
 Gendre, B., Atteia, J. L., Boër, M., et al. 2012, *ApJ*, 748, 59
 Goldstein, A. 2010, *GCN Circular*, 11403
 Golenetskii, S., Aptekar, R., Frederiks, D., et al. 2010, *GCN Circular*, 11400
 Golenetskii, S., Aptekar, R., Frederiks, D., et al. 2013, *GCN Circular*, 14417
 Gorbovskoy, E. S., Lipunova, G. V., Lipunov, V. M., et al. 2012, *MNRAS*, 421, 1874
 Gorosabel, J., Terron, V., Fernandez, M., et al. 2009, *GCN Circular*, 9782
 Gotz, D., Mereghetti, S., Paizis, A., et al. 2010, *GCN Circular*, 11396
 Guidorzi, C., Smith, R. J., Mundell, C. G., et al. 2010, *GCN Circular*, 11397
 Guidorzi, C., Stamatikos, M., Landsman, W., et al. 2008, *GCN Report*, 139
 Haislip, J. B., Nysewander, M. C., Reichart, D. E., et al. 2006, *Nature*, 440, 181
 Hartoog, O. E., Wiersema, K., Vreeswijk, P. M., et al. 2013, *MNRAS*, 430, 2739
 Immler, S., Sakamoto, T., Page, K. L., et al. 2010, *GCN Report*, 304
 Jakobsson, P., Fynbo, J. P. U., Paraficz, D., et al. 2005, *GCN Circular*, 4029
 Jelínek, M., Castro-Tirado, A. J., de Ugarte Postigo, A., et al. 2010, *Advances in Astronomy*, 2010
 Jelínek, M., Castro-Tirado, A. J., & Gorosabel, J. 2012a, *GCN Circular*, 13888
 Jelínek, M., de Ugarte Postigo, A., Castro-Tirado, A. J., et al. 2005, *GCN Circular*, 4227
 Jelínek, M., Gómez Gauna, E., & Castro-Tirado, A. J. 2013, in *EAS Publications Series*, Vol. 61, *EAS Publications Series*, ed. A. J. Castro-Tirado, J. Gorosabel, & I. H. Park, 475–477
 Jelínek, M., Gorosabel, J., Castro-Tirado, A. J., et al. 2012b, *Acta Polytechnica*, 52, 010000
 Jelínek, M., Kubánek, P., Gorosabel, J., et al. 2008, *GCN Circular*, 7648
 Kann, D. A., Laux, U., & Stecklum, B. 2010, *GCN Circular*, 11236
 Kann, D. A., Stecklum, B., & Ludwig, F. 2013, *GCN Circular*, 14593

Klebesadel, R. W., Strong, I. B., & Olson, R. A. 1973, *ApJ*, 182, L85+
Klotz, A., Gendre, B., Boer, M., & Atteia, J. L. 2012a, *GCN Circular*, 13107
Klotz, A., Gendre, B., Boer, M., & Atteia, J. L. 2012b, *GCN Circular*, 13887
Krimm, H., Barbier, L., Barthelmy, S., et al. 2005, *GCN Circular*, 4020
Krühler, T., Fynbo, J. P. U., Geier, S., et al. 2012, *A&A*, 546, A8
Kubánek, P., Jelínek, M., Gorosabel, J., et al. 2008, *GCN Circular*, 7603
Kubánek, P., Jelínek, M., Nekola, M., et al. 2004, in *AIP Conf. Proc.* 727: *Gamma-Ray Bursts: 30 Years of Discovery*
Laskar, T., Zauderer, A., & Berger, E. 2012, *GCN Circular*, 13903
Mangano, V., Parsons, A., Sakamoto, T., et al. 2008, *GCN Report*, 144
Mao, J., Guidorzi, C., Markwardt, C., et al. 2008, *GCN Report*, 132
Mao, J., Margutti, R., Sakamoto, T., et al. 2009, *GCN Report*, 204
Marshall, F. E., Antonelli, L. A., Burrows, D. N., et al. 2011, *ApJ*, 727, 132
Marshall, F. E., Barthelmy, S. D., Burrows, D. N., et al. 2008, *GCN Report*, 129
Melandri, A., Kobayashi, S., Mundell, C. G., et al. 2010, *ApJ*, 723, 1331
Mirabal, N., Halpern, J., Tonnesen, S., Eastman, J., & Prieto, J. 2005, <http://user.astro.columbia.edu/~jules/grb/051109a/>
Mirabal, N., Halpern, J. P., Tonnesen, S., et al. 2006, in *American Astronomical Society Meeting Abstracts*, Vol. 207, American Astronomical Society Meeting Abstracts, 210.02
Moin, A., Chandra, P., Miller-Jones, J. C. A., et al. 2013, *ApJ*, 779, 105
Norris, J., Barbier, L., Burrows, D., et al. 2005, *GCN Circular*, 4013
Pagani, C., Barthelmy, S. D., Baumgartner, W. H., et al. 2012, *GCN Circular*, 13886
Quimby, R., Fox, D., Hoefflich, P., Roman, B., & Wheeler, J. C. 2005, *GCN Circular*, 4221
Rabaza, O., Jelínek, M., Castro-Tirado, A., et al. 2013, *Review of Scientific Instruments*, 84, 114501
Racusin, J. L., Karpov, S. V., Sokolowski, M., et al. 2008, *Nature*, 455, 183
Rau, A., Kienlin, A. V., Hurley, K., & Lichti, G. G. 2005, *A&A*, 438, 1175
Resmi, L., Misra, K., Castro-Tirado, A. J., et al. 2012, *MNRAS*, 427
Rumyantsev, V. & Pozanenko, A. 2008, *GRB Coordinates Network*, 7857
Rumyantsev, V., Shakhovkoy, D., & Pozanenko, A. 2010, *GCN Circular* 11255
Sbarufatti, B., Barthelmy, S. D., Gehrels, N., et al. 2012, *GCN Circular*, 13123
Sbarufatti, B., Parsons, A., Sakamoto, T., et al. 2008, *GCN Report*, 142
Siegel, M. H., Kuin, N. P. M., Holland, S., et al. 2013, *GCN Report*, 409
Sollerman, J., Fynbo, J. P. U., Gorosabel, J., et al. 2007, *A&A*, 466, 839
Tanvir, N. R., Fynbo, J. P. U., Melandri, A., et al. 2012, *GCN Circular*, 13890
Tanvir, N. R., Levan, A. J., Matulonis, T., & Smith, A. B. 2013, *GCN Circular*, 14567
Tello, J. C., Gimeno, R., Gorosabel, J., et al. 2012, *GCN Circular*, 13835
Ukwatta, T. N., Stamatikos, M., Maselli, A., et al. 2013, *GCN Report*, 444
van Paradijs, J., Groot, P. J., Galama, T., et al. 1997, *Nature*, 386, 686
Yuan, F., Rykoff, E. S., Schaefer, B. E., et al. 2008, in *American Institute of Physics Conference Series*, Vol. 1065, American Institute of Physics Conference Series, ed. Y.-F. Huang, Z.-G. Dai, & B. Zhang, 103–106
Zafar, T., Watson, D., Elíasdóttir, Á., et al. 2012, *ApJ*, 753, 82
Zheng, W., Shen, R. F., Sakamoto, T., et al. 2012, *ApJ*, 751, 90

Table 3:

GRB 050525A: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.195	39×10 s	16.51	0.39	R

Note — Published by Resmi et al. (2012)

Table 4:

GRB 050824: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.1763		18.22	0.35	R
0.3462		19.11	0.32	R
1.0249		19.67	0.33	R
2.9091		19.33	0.20	R

Note — Published by Sollerman et al. (2007)

Table 5:

GRB 050922C: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.0694	40	14.58	0.35	R
0.3752	900	17.01	0.39	R
0.6193	900	18.53	0.59	R

Table 6:

GRB 051109A: Observing log of BOOTES-1B

$\Delta T[s]$	exp[s]	mag	dmag	filter
59.7	10	15.67	0.35	R
122.2	74	16.02	0.19	R
257.9	41	16.65	0.41	R
756.6	205	17.18	0.22	R
1021.5	313	17.68	0.26	R
508.4	908	16.98	0.54	I

Table 7:

GRB 080330: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.1061	7	16.52	0.23	clear
0.3752	210	16.61	0.13	clear
0.6193	588	17.16	0.14	clear
0.8547	825	17.45	0.15	clear
1.0915	862	17.29	0.13	clear
1.3384	905	17.42	0.16	clear

Table 8: GRB 090813: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.175	10×10	17.9	0.3	clear

Table 9: GRB 100418A: Observing log of BOOTES-2

$\Delta T[h]$	exp[s]	mag	dmag	filter
1.78	1638	19.785	0.215	clear
2.09	597	19.127	0.127	clear
2.55	534	18.774	0.087	clear
2.72	656	18.668	0.073	clear
3.10	239	18.706	0.106	clear
3.43	238	18.759	0.189	clear
4.70	3908	19.067	0.108	clear
6.19	4328	18.897	0.115	clear
7.39	551	18.493	0.078	clear
77.3	14830	20.475	0.202	clear
125.6	12482	20.970	0.208	clear

Table 10: GRB 100901A: Observing log of BOOTES-2

$\Delta T[h]$	exp[s]	mag	dmag	filter
10.202	268	17.52	0.08	R
10.719	415	17.61	0.07	R
11.230	354	17.67	0.09	R
11.734	238	17.99	0.16	R
12.346	730	17.78	0.13	R
12.980	759	17.68	0.12	R
13.239	759	17.82	0.16	R
13.971	997	18.21	0.12	R
14.611	1101	18.32	0.14	R
33.791	4012	19.35	0.19	R

Table 11: GRB 101112A: Observing log of BOOTES-2

$\Delta T[s]$	exp[s]	mag	dmag	filter
595.0	16	16.00	0.19	r'
631.8	8	16.10	0.29	r'
664.9	7	16.46	0.34	r'
697.8	7	16.30	0.25	r'
731.0	7	15.52	0.18	r'
766.1	11	15.56	0.13	r'
800.9	7	15.52	0.17	r'
833.8	7	15.24	0.12	r'
891.2	44	15.92	0.13	r'
973.7	69	16.33	0.20	r'
1044.0	69	16.62	0.23	r'
1124.2	41	17.09	0.36	r'
1252.7	115	17.44	0.25	r'
1393.8	116	17.86	0.38	r'
1629.5	255	18.57	0.48	r'

Table 12: GRB 110213A: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
15.5	100×30	18.29	0.30	clear

Table 13: GRB 120327A: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.955	654	17.50	0.12	clear
1.140	674	17.65	0.12	clear
1.337	748	17.82	0.13	clear
1.533	660	18.24	0.21	clear
1.718	673	18.17	0.21	clear
1.905	656	18.59	0.29	clear

Table 14: GRB 121024A: Observing log of BOOTES-1B

$\Delta T[h]$	exp[s]	mag	dmag	filter
0.900	1200	18.2	0.5	clear

Table 15: GRB 130418A: Observing log of BOOTES-1B and BOOTES-2

$\Delta T[h]$	exp[s]	mag	dmag	filter
1.514	3×15 s	17.09	0.08	clear
1.529	3×15 s	16.95	0.07	clear
1.544	3×15 s	16.90	0.06	clear
1.558	3×15 s	16.62	0.07	clear
1.573	3×15 s	17.03	0.07	clear
1.590	4×15 s	16.92	0.06	clear
1.610	4×15 s	17.04	0.07	clear
1.749	7×15 s	17.22	0.05	clear
1.865	60 s	16.92	0.18	r'
1.884	4×15 s	17.34	0.09	clear
2.054	7×15 s	17.45	0.07	clear
2.089	7×15 s	17.46	0.06	clear
2.209	6×15 s	17.47	0.07	clear
2.326	6×15 s	17.56	0.08	clear
2.444	6×15 s	17.71	0.09	clear
2.562	6×15 s	17.68	0.08	clear
2.798	22×60 s	17.40	0.04	i'
3.061	15×60 s	17.90	0.09	r'
3.333	15×60 s	17.98	0.09	r'
3.604	15×60 s	17.90	0.09	r'
3.866	15×60 s	18.05	0.11	r'
4.130	15×60 s	18.53	0.19	r'
4.449	20×60 s	18.42	0.14	r'
4.808	20×60 s	18.61	0.23	r'

Table 16: GRB 130505A: Observing log of BOOTES-2

$\Delta T[h]$	exp[s]	mag	dmag	filter
12.488	51×60 s	19.26	0.06	clear